

obituary

Jacques Lucien Monod died at his family home in Cannes on May 31, 1976 at the age of 66. He was one of the foremost leaders of the revolution in molecular biology, helping to lay the framework of our understanding of gene action and protein synthesis. Monod was a scientist of the first rank, both in his experimental work and in his ideas. By his scientific research and by his *Essay on the Natural Philosophy of Modern Biology* (translated into English as *Chance and Necessity*) he has left an indelible mark on the intellectual history of the 20th century.

Monod was born in Paris in 1910. When he was seven his family moved to Cannes where he lived and studied till he was eighteen, so that he thought of himself more a man of the Midi than a Parisian. His father was a painter, an unusual vocation at that time for one of Huguenot stock, coming from a family which had produced many doctors, pastors, civil servants and academics. His mother was American, a native of Milwaukee, the daughter of a New England mother and a Scottish immigrant father. Early

influences were his father, who in addition to his artistic sensibilities had a strong interest in science and in Darwin in particular; also his Greek master, a scholar whom he admired for his civilised attitude to life. Scientifically, he acknowledged among his immediate elders the impact of George Teissier, André Lwoff, Boris Ephrussi and Louis Rapkine. Perhaps most important of all was his year's stay, in 1936, with Morgan's group at Caltech. Their full, free and critical discussions, together with the easy personal relationships between people of different ages, were a revelation to him and strongly influenced his style of organising research.

In his scientific career Monod, though never seriously impeded, did not get off to a flying start as many young men do nowadays. It was at the beginning of the war, after a famous reply to André Lwoff ("L'adaptation enzymatique? Connais pas!") that he first became aware of the nature of the phenomenon he was studying. Only after the war, when he had joined the Pasteur under Lwoff, did he fully re-

cognise the depth of the problem which was to become his life's work. By then he was 37. But once having recognised it, he pursued it with tenacity, versatility and imagination. His logic was relentless; his intuition variable but profound. No wonder that many of his younger colleagues came to feel that to work with him was a scientific education in itself.

The results are now in every textbook. There is no space here to follow the story in all its details, nor to show how the commonplaces of today grew out of the confusions of yesterday. The concentration on β -galactosidase; the arrival of Mel Cohn ("acquisition précieuse") who knew about proteins and also how to use the Tiselius apparatus; the proof that the appearance of enzyme activity represented *de novo* synthesis (a big surprise at the time); the skilful use of lactose analogues to separate the inductive from the substrate activity and the discovery of the permease and the transacetylase. Finally the grand collaboration with François Jacob (from the other end of the corridor) leading to their immensely skilful dissection of the inductive process by genetics; the realisation, from certain mutants, that the synthesis of all three proteins could be turned on and off together (the operon); the postulate that the *i* gene product was a protein—the inhibitor—and the famous PaJaMo experiment of Pardee, Jacob and Monod which suggested that the message was unstable. It is difficult now to recall that at that time the ribosomal RNA was assumed to be the message. The realisation that the ribosome was a reading head, which could read any message, came as a great flash of understanding. After that the road to the genetic code was wide open.

Meanwhile Monod, with Jacob and Changeux, had recognised that the properties required for the inhibitor were, at first sight, unusual for a protein. On reflection, however, they realised that such properties were in fact common—their existence had simply not been appreciated. Thus was born the theory of allostérie. Various earlier workers (including those studying haemoglobin) had glimpsed the idea but had not recognised its generality and its profound importance. For now one could see how any metabolic pathway could be linked, control-wise, to any other: Without this type of mechanism even the simplest organisms

could not regulate themselves and higher organisms could not exist.

In 1969 Monod gave the Robbins Lectures at Pomona College in California. He used the occasion to develop and make precise his general ideas about biology, man and society. The lectures became a book, originally written in English, rewritten by him in French under the title *Le Hasard et la Nécessité*. Its publication made a strong impact and it became a best-seller. It aroused the almost united opposition of the French intellectual establishment which has always preferred Marx, Freud and Teilhard de Chardin to Darwin and Mendel. Written with force and clarity, in an unmistakable personal style, it presented a view of the universe that to many lay readers appeared strange, sombre, arid and austere. This is all the more surprising since the central vision of life that it projected is shared by the great majority of working scientists of any distinction. It would be difficult to find a better example to display the deep rift between science and the rest of our culture.

Monod was not aloof from public affairs. He was a persistent critic of the French University system and of the way in which French science was supported. Thus it was not entirely surprising that in 1971 he accepted the invitation to become Director-General of the Pasteur Institute. This decision came partly from his strong sense of duty; he was naturally reluctant to have to give up his research and his writing, but the Institute was in a bad way, having become desperately short of money. Monod threw himself wholeheartedly into his new job. He tried many things: appeals for funds, both public and private; the setting up of a production subsidiary with the aim to exploit useful ideas from the research side of the Institute; various economies and a limited reduction of staff. Finally

he toyed with a scheme, strongly opposed by many of his colleagues, to move the laboratory outside Paris. But the opposition to such a move was too strong and the sums of money required too great; only the government could supply them, a source he somewhat distrusted, as he feared for the Institute's independence. Looking back one can see that the Pasteur had to change and to change radically. It needed a scientist of Monod's stature to make the changes possible and reasonably palatable.

Science was the dominant activity in Monod's life but it was not the only one. During the war he worked for the French underground, receiving recognition for this perilous work from both the French and the American governments. He became a keen mountaineer only to give it up for sailing; the characteristic mixture of discipline and freedom appealed strongly to his temperament. He would sail his 37' boat single-handed or with the assistance of a mere amateur. Having a wide intellectual curiosity, he was remarkably well read, both in classical and modern authors—Camus was a personal friend. But his main passion outside science was music. He both played the cello and conducted. In his twenties he even wondered whether to give up science for music, and all through his life he tried to find time to make music with his friends.

Monod was a man of great personal charm. His English was perfect, though simpler than his French. Thanks to his good ear and his American mother, he spoke it without any trace of the heavy accent which most Frenchmen find difficult to discard. Good-looking, though small of stature, he commanded attention by his intelligence, his clarity, his incisiveness and by the obvious breadth and depth of his interests. Never lacking in courage, he combined a debonair manner and an impish sense

of humour with a deep moral commitment to any issue he regarded as fundamental. He had great warmth for his friends and treated his students with affection and candour, as if they were members of his family. To others he could be charming but somewhat more remote. Though his creative powers flowered most abundantly in his scientific work he combined within himself, in a natural harmony, the scientist, the philosopher, the man of action and the musician. He might well have made a world reputation by concentrating on any one of these roles. Such a range of gifts is rare. It is fortunate for us that he chose science, otherwise the development of molecular biology would have been very different.

The formal outlines of Monod's career will be recorded here only briefly. He obtained his first degree in 1931 and his doctorate in 1941, both from Paris. He joined the Pasteur Institute in 1945 as Chef de Laboratoire, becoming Chef de Service in 1953, head of the department of Cellular Biochemistry in 1954 and Director-General in 1971.

His stay at Caltech in 1936 was supported by the Rockefeller Foundation. While at the Pasteur he held a chair at the University of Paris from 1959 to 1967, followed by a chair in Molecular Biology at the Collège de France from 1967 to 1972. From 1962 onwards he was a non-resident fellow of the Salk Institute.

Monod received many honours, including Foreign Membership of the Royal Society and the US National Academy, among others, and several prizes, culminating in the award of the Nobel Prize for Physiology and Medicine in 1965 which he shared with Lwoff and Jacob.

His wife, the former Odette Bruhl, whom he married in 1938, died in 1972. They had two sons, twins, who survive him. Both are scientists. F.H.C.C.